WORLD-CLASS OUTSTANDING INTERNATIONAL

PROGRAM | EXHIBITION | NETWORKING

CASE STUDY OF MORTON EFFECT EXPERIENCED DURING MECHANICAL TESTING OF A CENTRIFUGAL COMPRESSOR

PRESENTED BY

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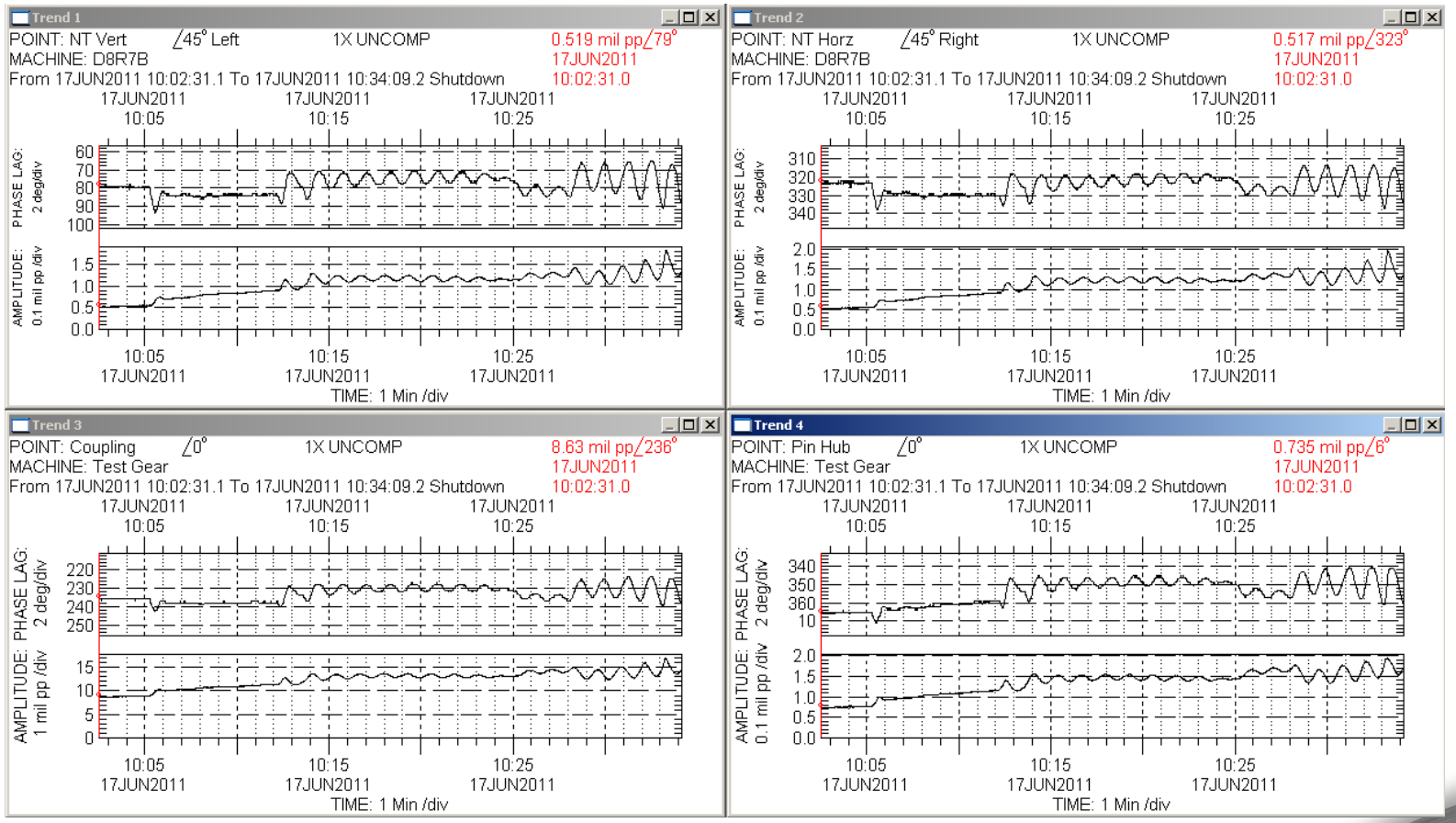
Background

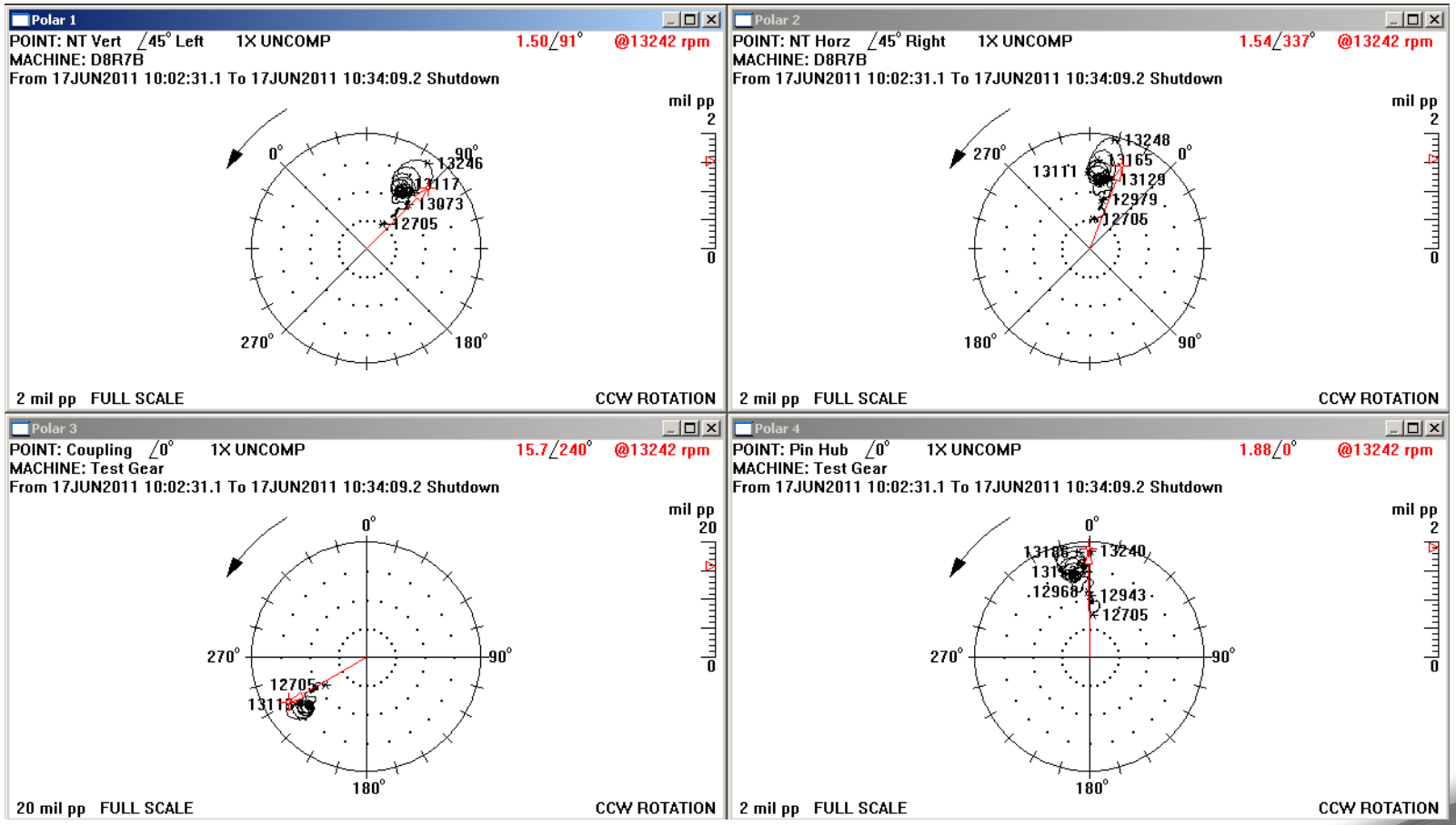
- High synchronous vibration was observed on the drive end of a centrifugal compressor during light load shop testing.
- The compressor was a single extended unit with a relatively large coupling, operating at a maximum continuous speed of 14,259 RPM.
- As vibration levels were similarly elevated on the shop gearbox, a displacement probe was mounted at the midspan of the coupling.

Trend Plot



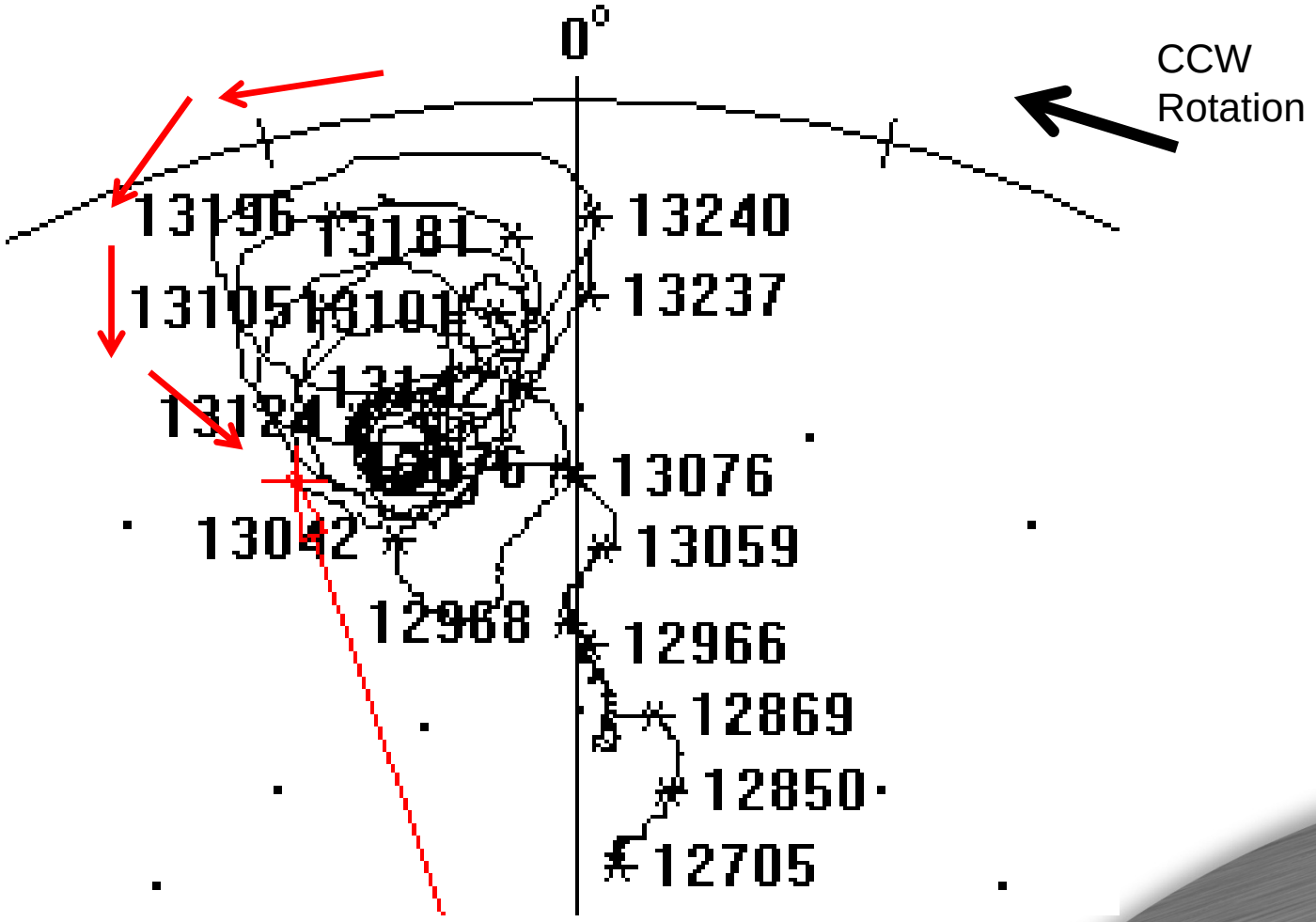
Note fluctuations of both 1x amplitude & phase at constant speed on the drive end of the compressor, coupling midspan, and pinion.

Polar Plot



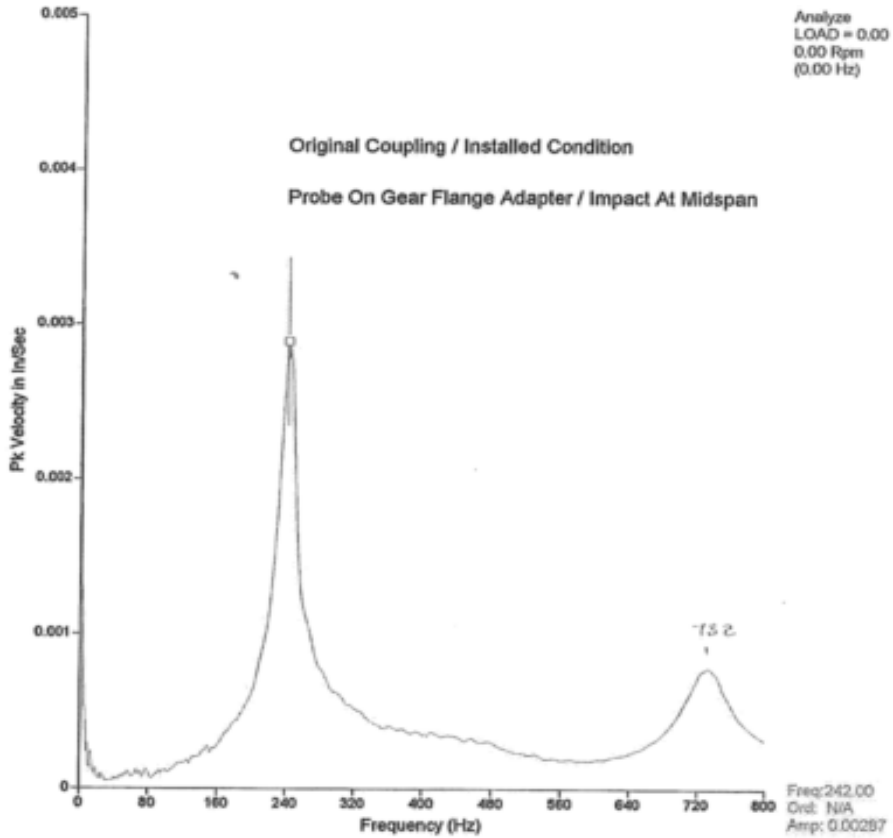
Amplitude and phase fluctuations are seen as time variant, cyclic, precession about a center point offset from the center axis

Polar Plot [Expanded View]



Precession is in the direction of shaft rotation

Ring Test Of Original Coupling In the Installed Condition



A natural frequency was identified at 242 Hz (14520 CPM) which was 2% above the maximum continuous speed of the compressor.

Question

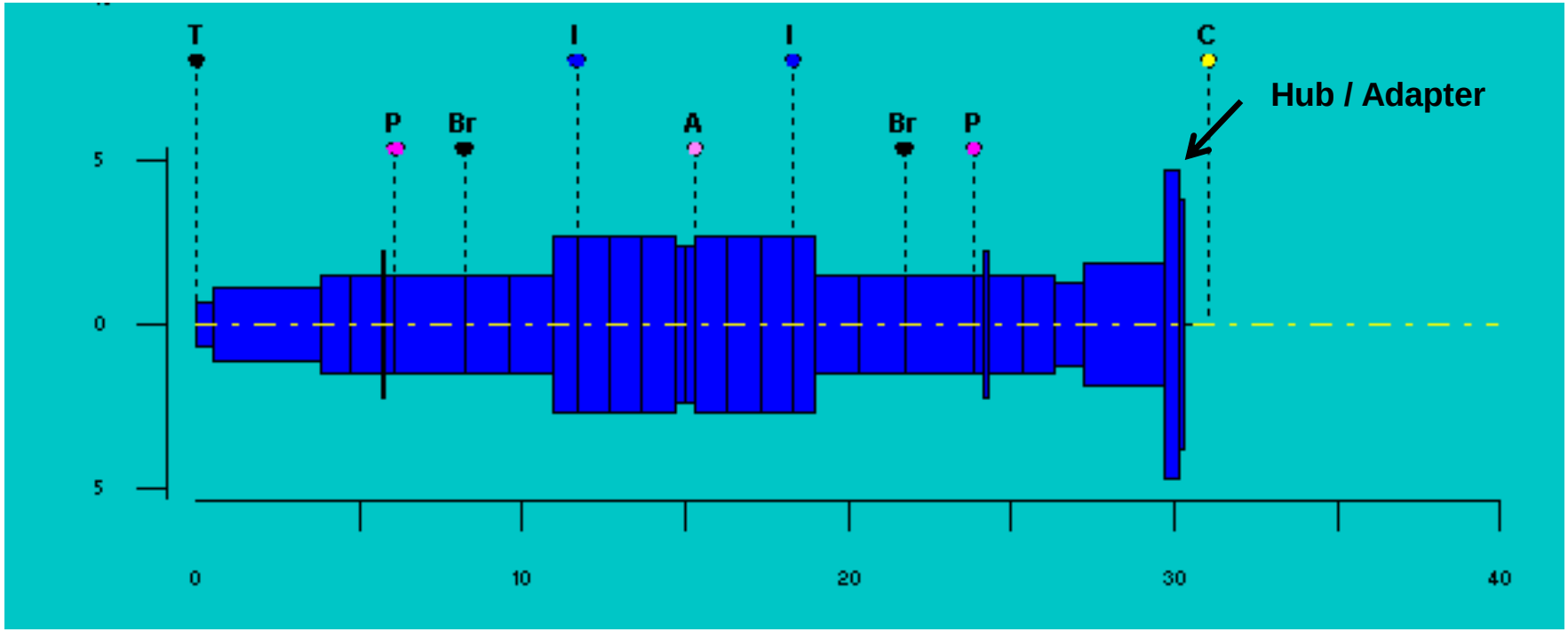
Was it the natural frequency of the compressor, gearbox and/or coupling

?

Action Taken

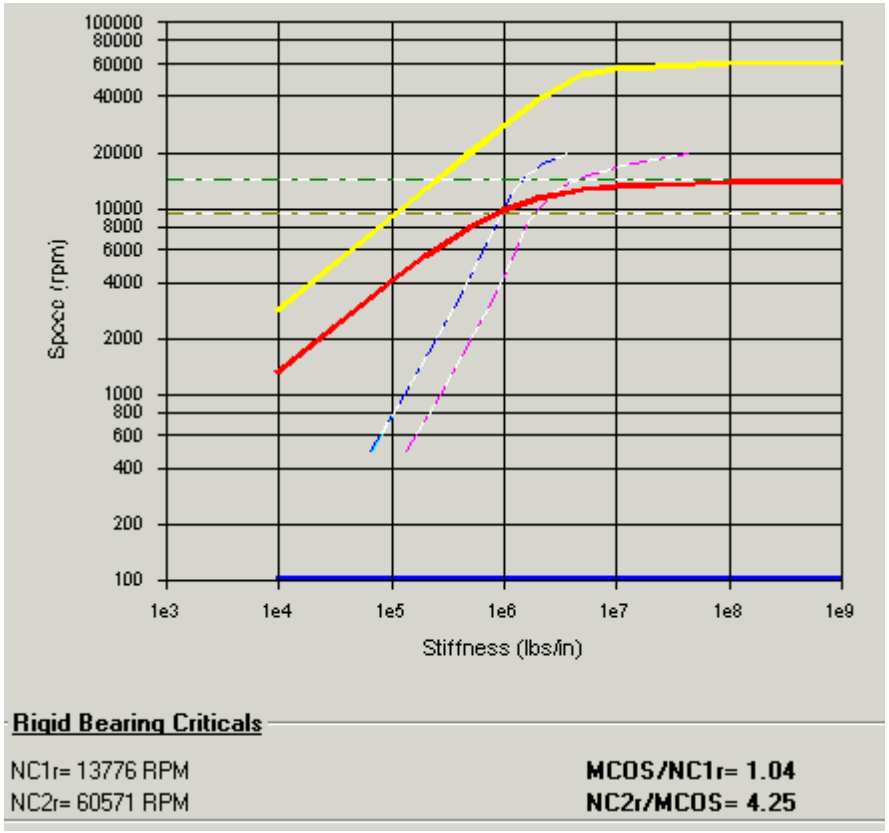
- The coupling ring test showed the greatest response on the gearbox side. Hence, a rotor dynamic study of the pinion was pursued.
- The pinion was removed from the case and dimensionally checked. The tilt pad bearings were also measured.
- The pinion was hung vertically from a strap and ring tested. The rotor model was adjusted to match the first two natural frequencies to within +/- 2%.

Rotor Model



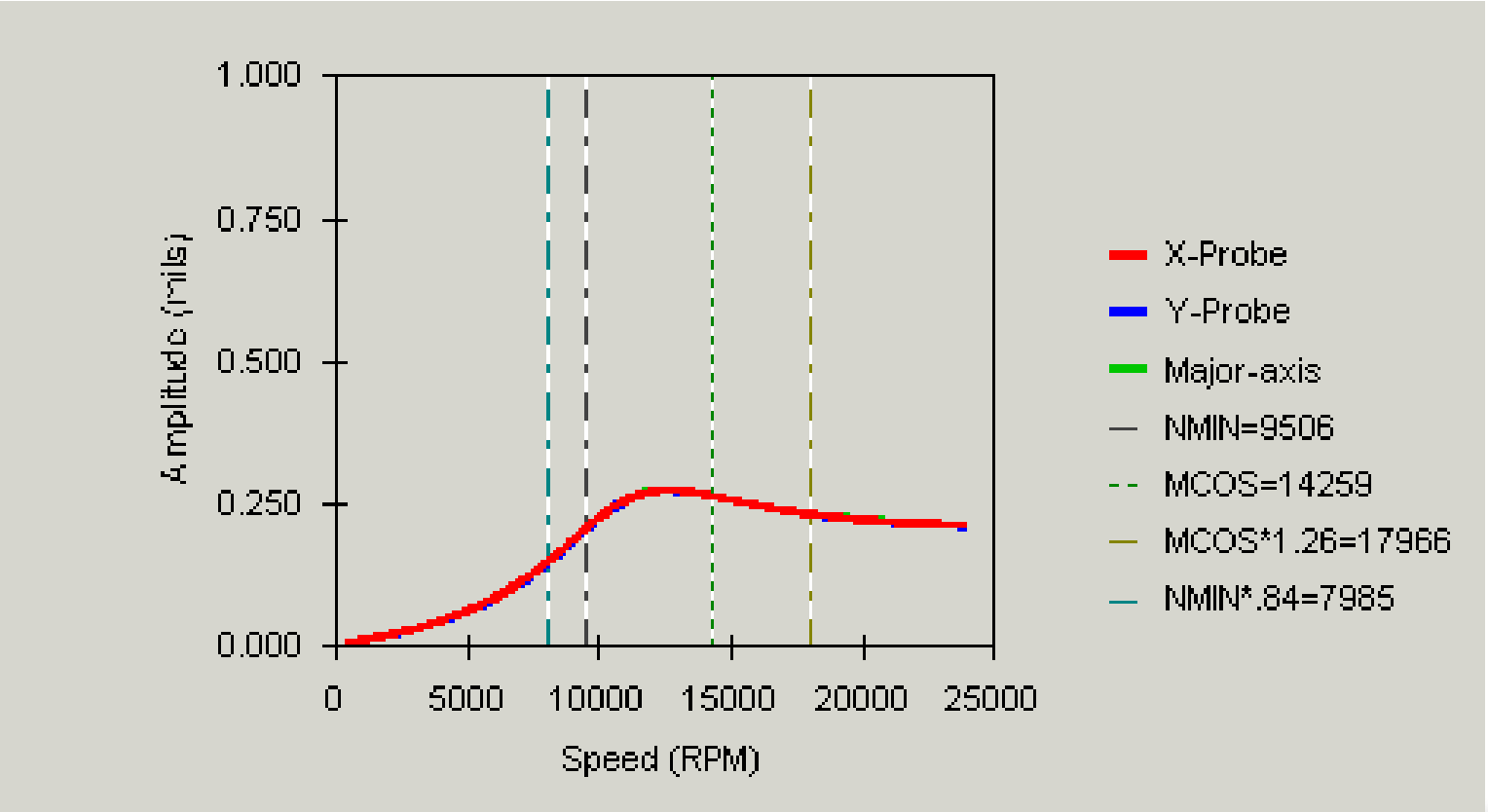
The hub / adapter was used to connect the production coupling to the test stand gear.

Undamped Critical Speed Map



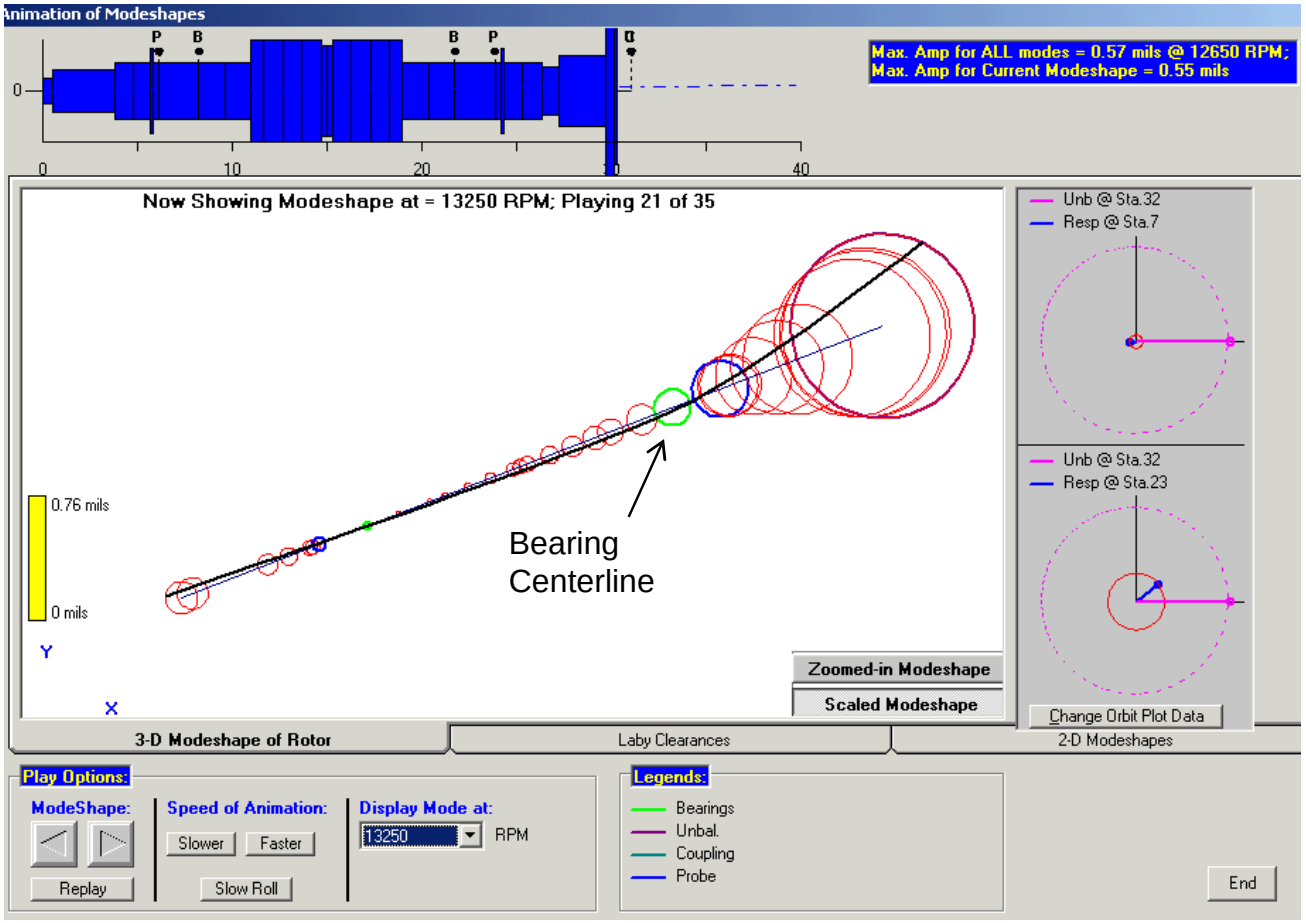
The first natural frequency on rigid supports was 13,776 CPM. This is in proximity with maximum continuous speed which indicates that the problem could not be corrected by changing the bearing characteristics.

Unbalance Response Plot



The peak response was at 12,600 RPM with an AF of 1.9 The bearing eccentricity ratio was 0.15.

Unbalance Response Mode Shape



This mode is highly influenced by overhung moment (coupling weight) and unbalance. Bearing influence is secondary.

Test Gearbox History

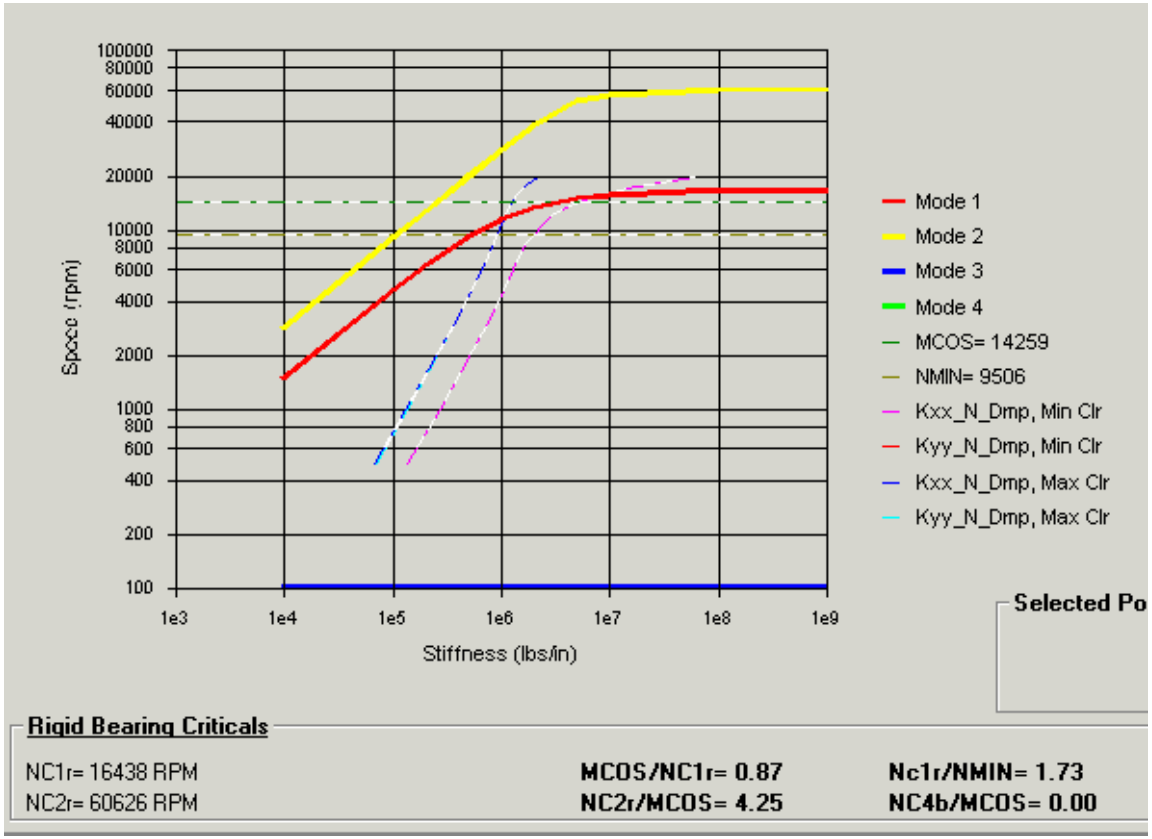
- Manufactured in 1965 with fixed profile bearings. Had a gear ratio of 1.362.
- Remanufactured in 1975. Gear ratio increased to 1.583. Retrofitted with tilting pad bearings.
- Later remanufactured to a gear ratio of 1.947.

Action Taken

- A titanium coupling spacer was procured and installed which reduced the half weight from 34.2 lbs to 21.2 lbs

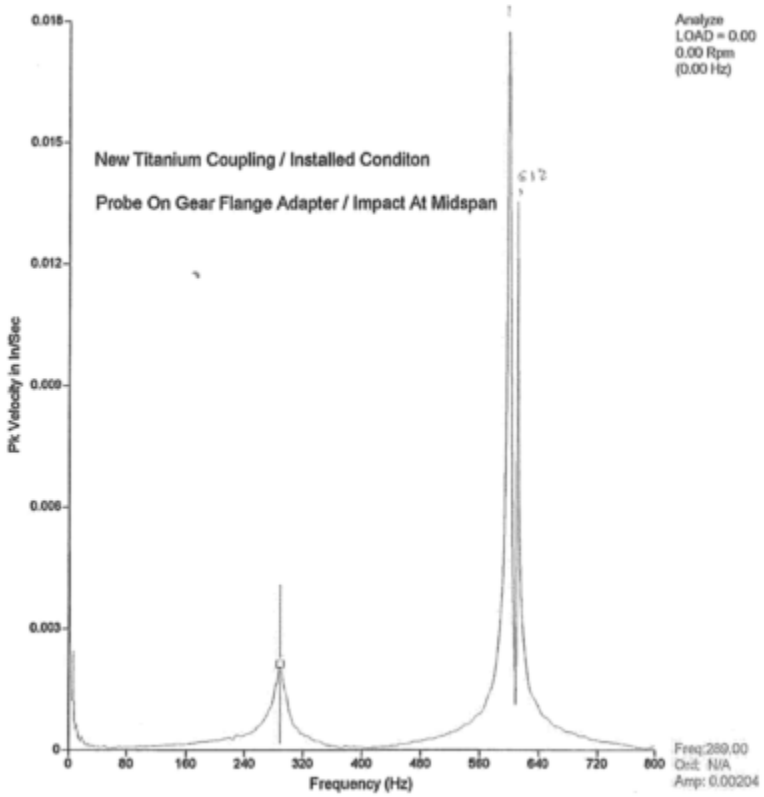
Undamped Critical Speed Map

(With Light Weight Coupling)



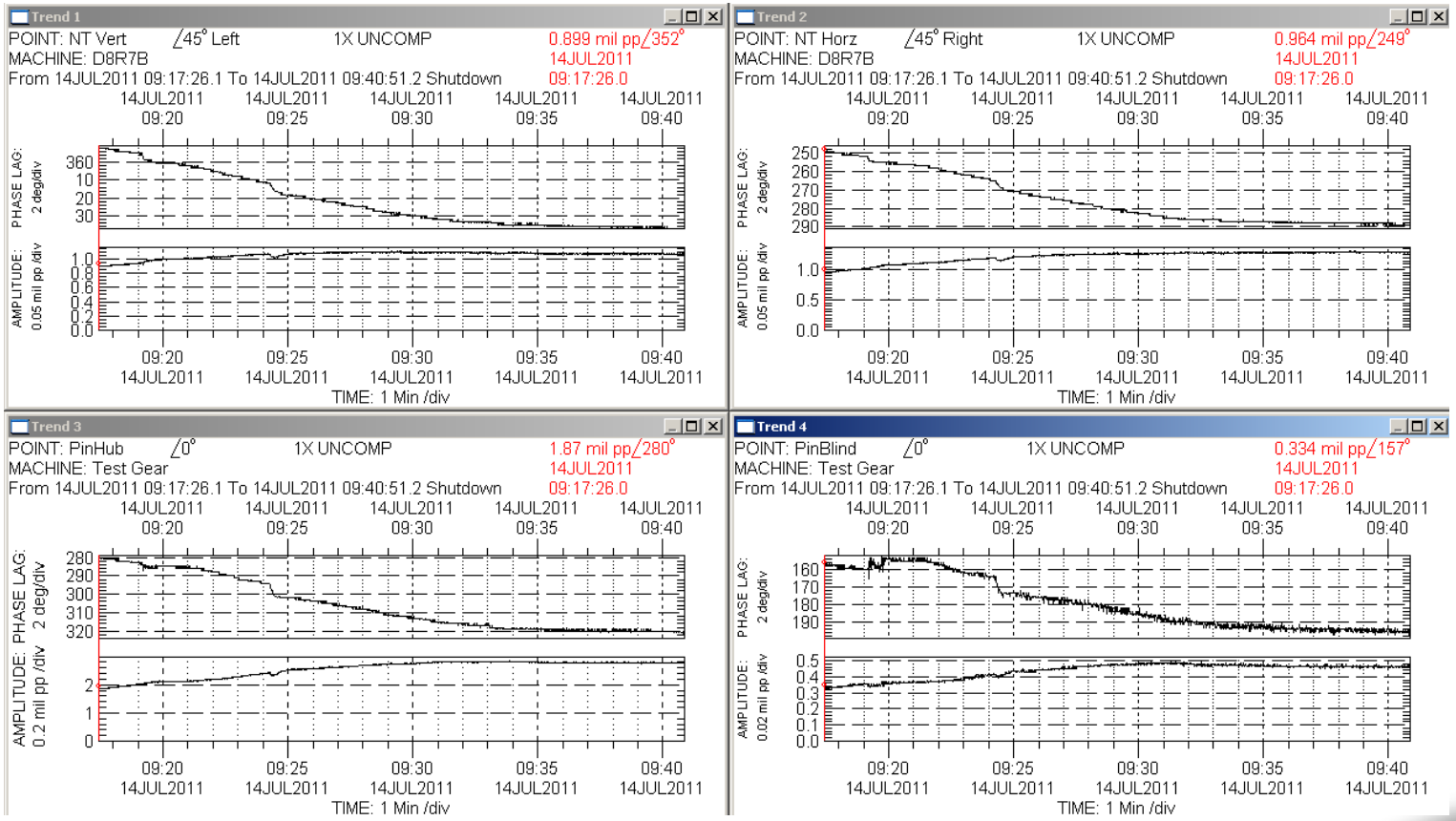
This change raised the first natural frequency on rigid supports from 13,776 CPM to 16,438 CPM which was 15% above maximum continuous speed.

Ring Test Of Light Weight Coupling Installed On the Test Gearbox



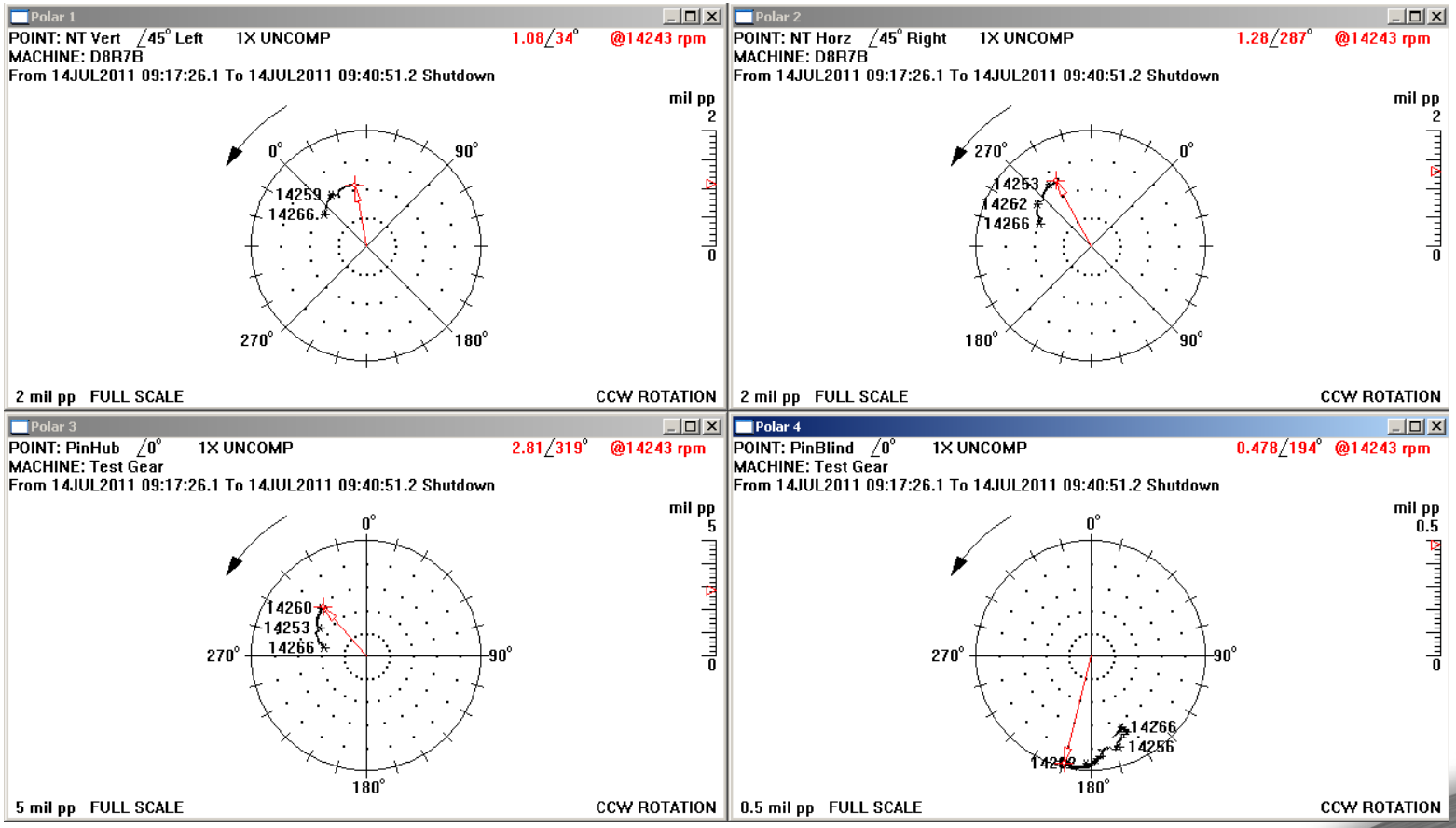
The natural frequency increased from 242 Hz (14520 CPM) to 289 Hz (17340 CPM) which was 22% above the maximum continuous speed.

Trend Plot *(with Light Weight Coupling)*



Vibration levels were lower. No longer fluctuations in amplitude and phase. Coupling was clocked to the most favorable angular position. However, vibration levels were above API limit of 0.91 mil.

Polar Plot *(with Light Weight Coupling)*



Amplitude and phase slowly shifted with time but eventually settled out.

Test Stand Driver Limitation

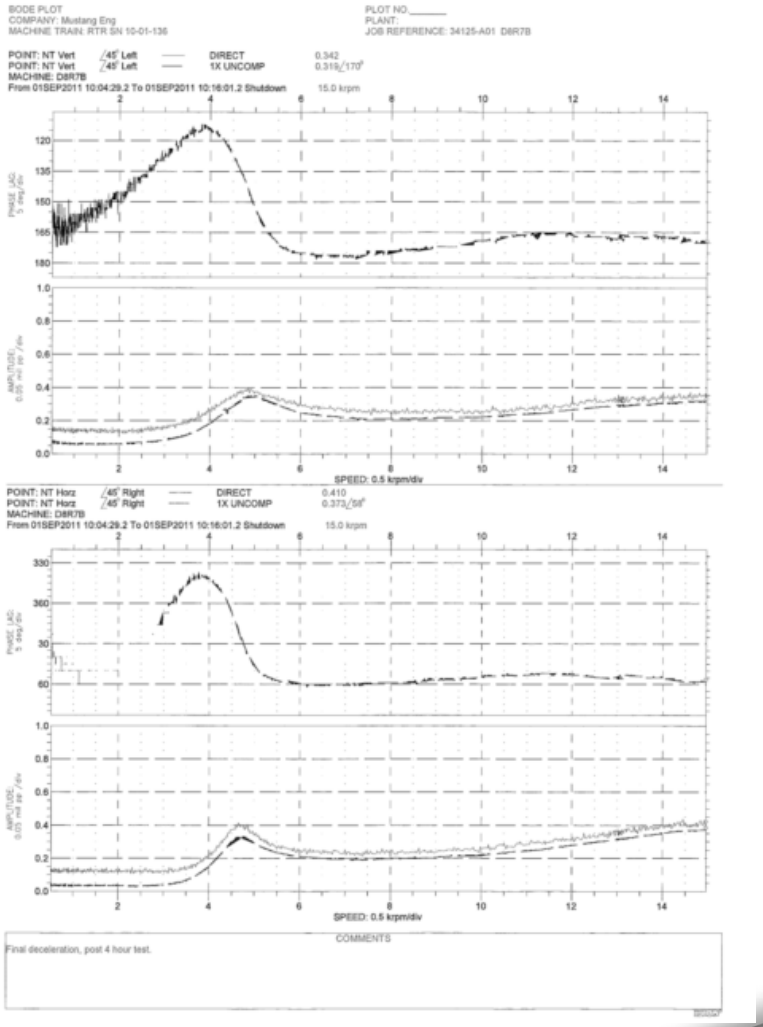
- Unable to increase gear load with test driver to push the critical speed sufficiently above maximum continuous speed.

Final Resolution

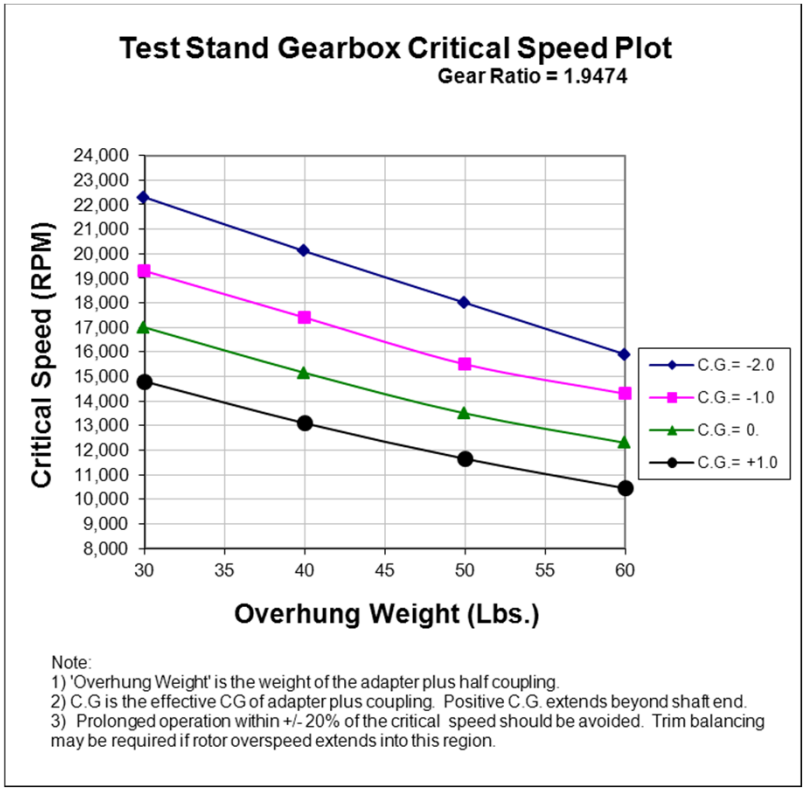
- The compressor was retested with the production gearbox.
- Vibration levels on the compressor and gearbox were steady and within API limits.

Bode Plot

During the customer witness test, the overall vibration levels on the compressor were stable at 0.30 - 0.4 Mil.



Corrective Action



A plot was provided to the Test Department which identified the pinion's critical speed as a function of coupling half weight and CG. This will enable them to avoid future operation in the vicinity of the critical speed.

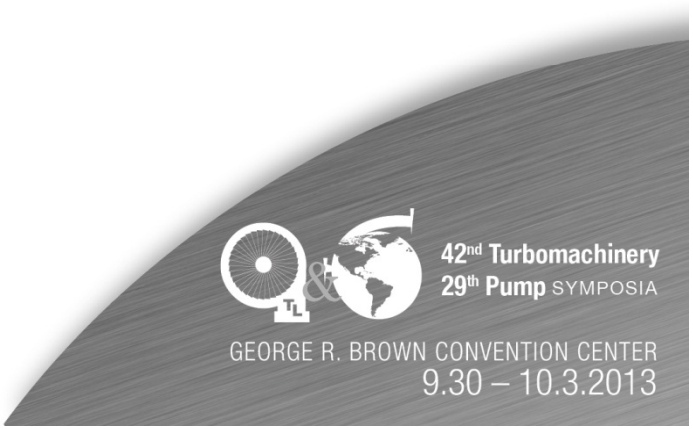
Summary / Conclusions

- Morton Effect was observed during production testing while using a Test Stand gearbox.
- Classic Morton Effect occurs under the following conditions:
  - Low bearing running eccentricity
  - Synchronous amplitudes such that the bearing minimum film thickness rotates in synchronous precession with shaft rotation resulting in localized shaft heating.

Summary / Conclusions [continued]

- Coupling modification raised the pinion's natural frequency but was insufficient to correct problem.
- Successful test resulted after changing to the production gearbox.
- Long term corrective action consisting of providing the means for the Test Department to evaluate hardware selection pre-test.

Questions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